



## Agro-morphological diversity in turmeric (*Curcuma longa*) accessions collected from north-eastern India

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Received: 24 November 2010; Revised accepted: 8 May 2011

### ABSTRACT

Eightythree turmeric accessions from five states of north-eastern India were compared under high humid sub-tropics at mid altitude (1 000 m elevation) for ten quantitative characters using multivariate methods, including clustering and principal component analysis to assess the patterns of morphological variation. Plant height, leaf number, primary fingers size and suckers number showed positive and significant association with rhizome yield. The accessions were grouped into four clusters and within each group, morphological variations were of low order. The first four principal components contributed 75% of the variability. Both clustering and principal component analysis have proved to be effective methods in grouping turmeric accession according to their morphological characteristics and better understanding of the existing variability that will facilitate genotypic selection for crop improvement.

**Key word:** Cluster analysis, *Curcuma longa*, Morphology, Principal component analysis, Variability

The genus *Curcuma* L. contains many taxa of economic, medicinal, ornamental and cultural importance, turmeric (*C. longa* L.) being the best known. The highest diversity is existed in India and Thailand, with at least 40 species in each area (Leong-Skornieikova *et al.* 2007). Turmeric is a triploid ( $2n = 3x = 63$ ) vegetatively-propagated rhizomatous crop. It is mainly cultivated in South East Asia with India being the largest producer and exporter.

In India, turmeric is one of the important spice crops and plays a vital role in the national economy. Turmeric spice is obtained from the underground rhizomes which after drying and processing, results in a bright yellow powder used as a natural food dye. In addition, the presence of various compounds like curcumin, the yellow coloured pigment, with pharmacological activities has broadened the commercial value of this crop (Ravindran *et al.* 2007). There is a long tradition of using turmeric in the Chinese and Ayurvedic systems of medicine. Modern biomedical research also attests the medicinal value of turmeric in a variety of ailments and

reported to have anti-inflammatory, anti-parasitic, antispasmodic, hypolipidemic, anti-cancerous and anti-fertility activity (Araujo and Leon 2001, Thakur *et al.* 2009).

Total production of turmeric in India during 2006–07 was ~0.86 million tonnes (Spices Board of India 2010). A high degree of variability has been reported in turmeric in India (Sasikumar and Sardana 1989, Nandi 1991, Korla *et al.* 1992, Babu *et al.* 1993, Sasikumar 2005). Conventional breeding is difficult in turmeric and hence genetic improvement of the crop is limited to germplasm selection and to eventual sport arising during vegetative propagation. Though some efforts have been made to identify the genetic potential of turmeric germplasm from India, very few studies have been conducted to characterize and evaluate the indigenous material of turmeric from north-eastern India (Pandey *et al.* 1990, Chandra *et al.* 1997). The existing variability in germplasm collections needs to be exploited to facilitate genotype selection.

The objective of the present study was to determine the patterns of distribution of morphological variation for ten quantitative characters in 83 turmeric germplasm collected from wide geographical range of north-eastern India (from the states of Asom, Meghalaya, Arunachal Pradesh, Mizoram and Manipur). Present investigation is aimed to discuss variability of these accessions based on agro-morphological traits.

### MATERIALS AND METHODS

The collection of turmeric genetic resources of north-

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eastern India as held at the Regional Station, National Bureau of Plant Genetic Resources (NBPGR), Shillong, Umiam, Meghalaya, includes 83 accessions which have been collected from five states (Asom: 41, Meghalaya: 16, Arunachal Pradesh: 11, Manipur: 2 and Mizoram: 13) of north-eastern India. These accessions were evaluated consecutively for two years, i.e. 2007–08 and 2008–09 in augmented block design at Umiam (1 000 m elevation), in rainfed, acid alfisol conditions (pH 5.2). The experimental field coordinates are 26°N latitude and 92°E longitude with annual temperature ranges between 6 °C and 29 °C and average rainfall ranges between 2 300 and 2 500 mm.

In 2007–08, the accessions were planted on third week of April, 2007 and harvested on January, 2008, and in 2008–09, planting and harvesting were done on first week of April, 2008 and first week of January, 2009. Each accession was grown in row plots of 2 m long and 1.5 m wide with row-to-row and plant-to-plant spacing of 50 cm and 30 cm respectively. The crop was grown with an amount of 200 kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 80 kg K<sub>2</sub>O/ha in the form of urea, diammonium phosphate and muriate of potash respectively. Two hand weeding were performed at 20 and 50 days after planting. For every accession, five individuals were used for recording the data except yield/ plot. A total of ten characters were recorded as follows: plant height, number of leaves (leaves on the main stem), leaf length, leaf width (recorded from the broadest portion of leaf lamina), suckers/ plant, rhizomes/ plant (total number of rhizomes including mothers and fingers), primary finger length, primary finger diameter, rhizome weight/plot and yield/plot. Observations on first five characters were recorded at maturity, i.e. one month before harvesting. Other characters were recorded after harvesting.

The mean value, standard deviation (SD), coefficient of variation (CV), maximum and minimum values (summary statistics) for each character was determined. Principal component analysis (PCA) of the mean data was performed by using SPSS statistical software (SPSS version 16.6 for

Windows, SPSS Inc. Chicago, USA). Ward's hierarchical clustering (Ward 1963) was used to assess diversity in turmeric accessions. Hierarchical clustering was done by SPSS software. The Z values were calculated from mean values and used for cluster analysis.

## RESULTS AND DISCUSSION

### *Descriptive statistics*

The mean, maximum, minimum, standard deviations and coefficients of variation of the ten morphological variables are given in Table 1. The accessions exhibited large variation for rhizome weight/ plant, suckers/ plant, yield/ plot and plant height as shown by their coefficients of variation.

Table 1 Agro-morphological characteristics of turmeric accessions

Trait	Mean	SD	Max	Min	CV (%)
Plant height(cm)	27.2	7.6	45.8	14.3	27.9
No. of leaves	8.0	0.7	9.8	6.0	9.2
Leaf length(cm)	53.7	9.5	75.8	34.8	17.7
Leaf width(cm)	15.8	1.9	19.5	10.4	12.0
Suckers/plant(no.)	2.1	0.9	6.2	1.2	41.4
Rhizomes/plant(no.)	5.3	0.7	7.8	3.9	14.0
Primary finger length(cm)	7.6	1.0	10.9	5.0	13.3
Primaryfinger diameter(cm)	2.0	0.2	2.8	1.6	10.5
Rhizome weight/ plant(g)	391.0	190.6	1 656.5	209.8	48.7
Yield/ plot(g)	2 583.4	987.6	6 550.0	900.0	38.2

Pearson correlation coefficients between ten morphological characters of the turmeric accessions are given in Table 2. Almost all the characters except number of rhizomes/ plant exhibited significant positive correlation with yield/ plot. Number of leaves, leaf width and primary finger diameter were significantly linked with rhizome weight/ plant. Number of rhizomes/ plant did not show significant

Table 2 Pearson correlation coefficients between ten morphological traits

	NL	LL	LW	NS	RP	PFL	PFD	RW	YP
PH	0.904**	0.622**	-0.172	0.275*	0.105	0.291**	0.330**	0.129	0.414**
NL		0.602**	-0.161	0.339**	0.132	0.262*	0.421**	0.257*	0.538**
LL			-0.294**	0.261*	0.051	0.335**	0.243*	0.082	0.255*
LW				0.029	0.273*	-0.271*	-0.244*	0.293**	0.319**
NS					0.111	-0.161	0.231*	0.125	0.345**
RP						-0.149	-0.107	0.158	0.201
PFL							0.252*	0.132	0.239*
PFD								0.265*	0.392**
RW									0.494**

\* $P=0.05$  \*\*  $P=0.01$

PH, Plant height; NL, no. of leaves; LL, leaf length; LW, leaf width; NS, suckers/plant; RP, rhizomes /plant; PFL, primary finger length; PFD, primary finger diameter; RW, rhizome weight/plot; YP, yield/ plot

association with rhizome weight/plant. Number of leaves, which had highest positive association with yield/plot, had high positive correlation with plant height, leaf length, primary finger length and primary finger diameter. Number of rhizomes/plant showed significant positive linkage with leaf width only.

#### PCA and cluster analysis on morphological traits

The PCA variable loadings, percentage of variance explained and cumulative variance for the first four principal components are given in Table 3. The first four principal components accounted for 75% of the total variance. The first principal component (PC1) accounted for 34% of total variance, and had factors with high contribution as plant height, leaf length, leaf width, yield/plot, primary finger diameter, number of leaves, primary finger length and rhizome weight/plant. All the variables except suckers/plant contributed positively towards PC1. The second principal component (PC2), accounting for an additional 18.7% of the total variation, depicted primarily the patterns of variation in suckers/plant, rhizomes/plant, rhizome weight/plant and yield/plot. Finally, third and fourth principal components (PC3 and PC4) contributed around 12% and 10% respectively of the variability present among the accessions for the characters used in the present study. The PC3 had high factor loadings for primary finger length, rhizome weight/plant and primary finger diameter, and PC4 explained the patterns of variation in rhizomes/ plant and primary finger length.

Table 3 Factor loadings of ten morphological characters for the first four principal components and percentage of variance accounted for each component

Trait	PC1	PC2	PC3	PC4
Plant height (cm)	0.85	-0.14	-0.24	0.19
Number of leaves	0.45	0.26	-0.45	-0.57
Leaf length(cm)	0.91	-0.04	-0.17	0.09
Leaf width (cm)	0.71	-0.30	-0.24	0.20
Suckers /plant (no.)	-0.15	0.83	0.09	0.13
Rhizomes/ plant (no.)	0.13	0.55	-0.37	0.46
Primary finger length (cm)	0.42	-0.40	0.55	0.36
Primary finger diameter (cm)	0.59	-0.12	0.33	-0.48
Rhizome weight/ plant (g)	0.40	0.54	0.49	-0.03
Yield/ plot (g)	0.69	0.49	0.25	-0.05
Percentage variance	34.475	18.711	12.046	9.960
Cumulative variance	34.475	53.185	65.231	75.191

Hierarchical clustering using Ward's method assembled accessions from the five states of north-eastern India into four clusters based on the ten morphological traits (Fig 1). The mean values of accessions falling in each cluster are presented in Table 4. Cluster 1 included 42 accessions (Asom: 18, Meghalaya: 8, Arunachal Pradesh: 7 and Mizoram: 9) having higher plant height, more number of leaves, larger

leaves and higher primary finger diameter. The accessions from cluster 2 (Asom: 5 and Meghalaya: 1) displayed highest number of suckers/plant, rhizomes/plant, rhizome weight/plant and yield/plot. In this group, leaf width and primary finger diameter were lowest among the clusters. Cluster 3 comprised thirteen accessions (Asom: 7, Arunachal Pradesh: 2, Mizoram: 3 and Manipur: 1) having longest rhizomes and lowest number of rhizomes/plant. The results displayed that cluster 4, comprising 22 accessions (Asom: 11, Meghalaya: 7, Arunachal Pradesh: 2, Mizoram: 1 and Manipur: 1) was separated from other clusters owing to its lowest mean values for yield/plot, rhizome weight/plant and plant height.

Table 4 Comparison using Ward hierarchical clustering of ten morphological traits of the four clusters

Trait	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Plant height (cm)	32.4	23.2	23.6	20.5
Number of leaves	8.3	8.0	7.3	7.8
Leaf length(cm)	60.8	50.4	47.7	44.8
Leaf width (cm)	16.9	13.8	15.6	14.3
Suckers/plant (no.)	1.9	4.4	2.0	2.1
Rhizomes/plant (no.)	5.4	6.2	4.8	5.2
Primary finger length (cm)	7.7	6.9	8.8	6.8
Primary finger diameter (cm)	2.1	1.8	2.0	1.9
Rhizome weight/plant (g)	405.0	837.3	332.0	277.4
Yield/plot (g)	2 923.2	3 504.2	2 255.8	1 877.3

The first two principal components were plotted to observe relationship between the clusters (Fig 2). All clusters showed clear separation on the biplot. Accessions IC394668 and IC545212 from Asom had high positive coefficients of both components and thus occupied extreme right corner of the upper half of the biplot. Accessions IC545139, IC545155 and IC394936, all from Asom, had high positive coefficients of PC2 but negative coefficients of PC1, and thus occupied the upper left corner of the biplot. Accessions IC394550 (Asom) and IC330435 (Manipur) having lower coefficient of PC2 and a positive coefficient of PC1, occupied the bottom right corner of the biplot. The cluster 1 on the positive of PC1, is characterized by taller height, larger leaves and large rhizomes (Fig 2). Cluster 2 on the positive of PC2 has higher number for suckers/plant, rhizome/plant, higher rhizome weight and yield/plot. Other two clusters (cluster 3 and 4) on the negative PC1 have lower values for most of the characters except cluster 3 with longer rhizomes. Biplot did not revealed clear grouping of accessions according to the geographical distribution.

The north-eastern region of India represents a geographical diverse area of varying altitude and temperature. A vast genetic variation is believed to exist among the indigenous materials of turmeric in north-eastern India. In last few years, several genotypes had been collected from

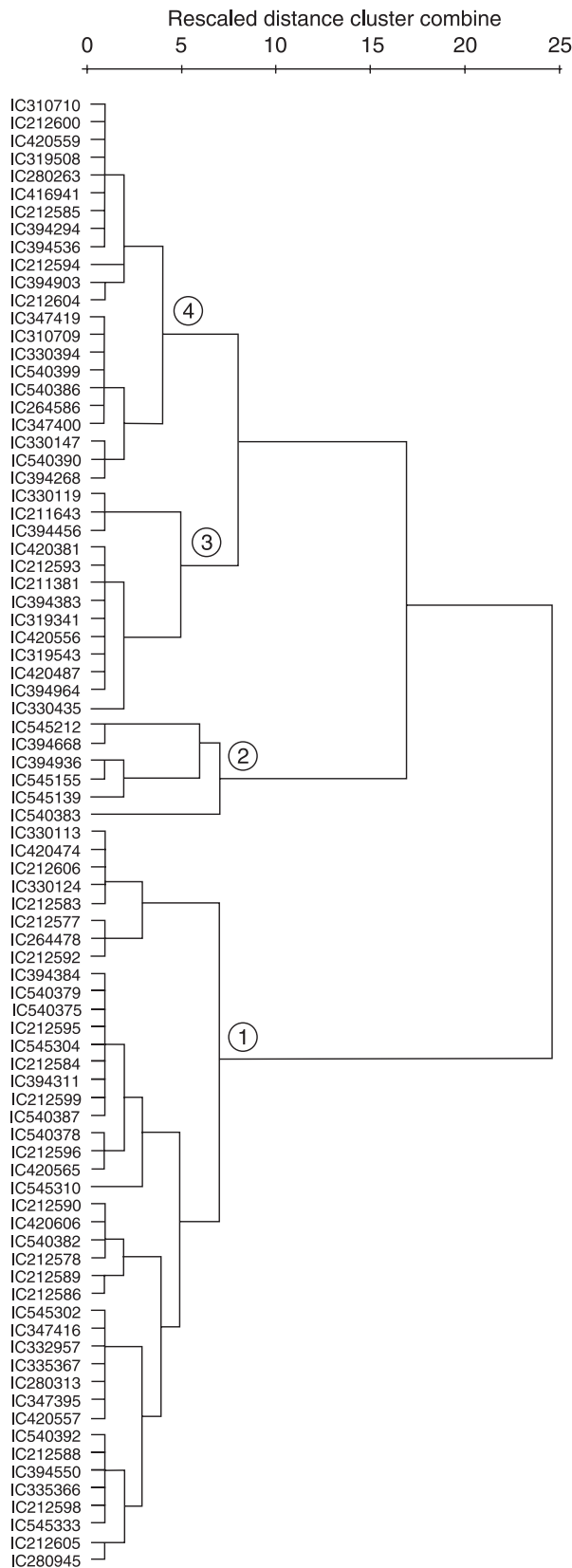


Fig 1 Grouping of the turmeric accessions on the basis of standardized squared Euclidean distance applied to Wards hierarchical analysis

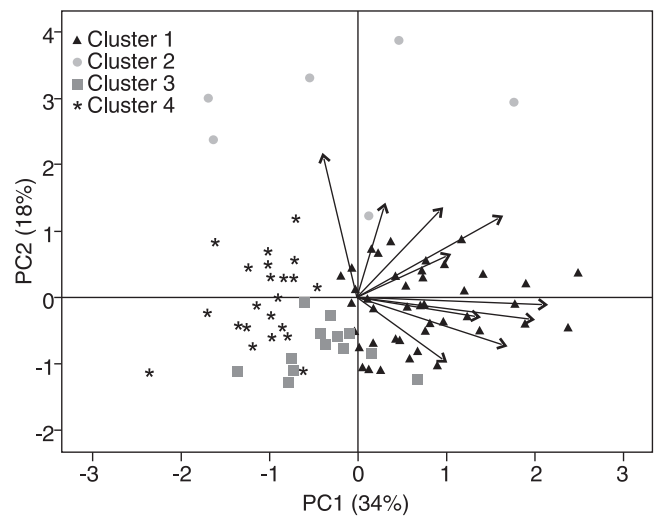


Fig 2 Plot of first- (PC1) and second-principal component (PC2) scores of turmeric accessions. Biplot vectors indicate strength and direction of factor loading for PC1 and PC2. Accessions belonging to different clusters are indicated by different symbols

this region (Pandey *et al.* 1990; Chandra *et al.* 1997). The genotypes collected from different altitudes of different states have shown diversity which could be grouped to form one or more complexes in broad sense (Pandey *et al.* 1990). Little attempts had been made in past to distinguish among these genotypes for identifying their genetic potential. The earlier studies carried out with a less number of genotypes, which is inadequate to depict an approximate picture of turmeric genetic resources of north-eastern India. The present investigation with 83 turmeric accessions showed that these genotypes represent a high amount of variation for rhizome yield and other yield attributing traits. This variability can be utilized for selecting high yielding genotypes.

The traits investigated in this study are important, as they have significant association with rhizome yield. The leaf number, leaf size, suckers number and rhizome size are important traits of turmeric for higher yield. Limited studies similar to the present one have been conducted in turmeric. However, several experiments have been carried out in different species (Morris 2007, 2008, 2009) which suggested that coefficients of variation, principal components and cluster analysis provide useful information about the variability present in germplasm collections and successfully been used to characterize genetic resources. On the basis of overall agro-morphological diversity, four genotypic clusters of different morphological groups were obtained. In PCA, the coordinations of accessions along the axes of PC1 and PC2 have identified the accessions correspond to different characteristics irrespective of their geographical distribution. The outcome of PCA was consistent with the results obtained through cluster analysis, whereby the major differences between the clusters were attributed to the same traits that

contributed most to PC1 and PC2. Our results are consistent with the earlier reports that both PCA and cluster analysis can disclose complex relationship between genotypes with equal effectiveness (Rezai and Frey 1990, Sukla *et al.* 2010).

In conclusion, PCA and cluster analysis have proved to be effective methods in grouping turmeric accessions that may facilitate effective utilization of the accession in crop-improvement programmes through selection, as conventional breeding is difficult in this crop. Moreover, correlation analysis of morphological traits indicated that tall plants having longer and broader leaves with higher number of suckers/plant will be an ideal plant type for higher rhizome yield. The north-eastern India is an important traditional belt for wide genetic diversity, thus requires considerable attention in this respect.

#### ACKNOWLEDGEMENTS

Authors acknowledge the efforts of Mr A K Deka, skilled supporting staff, Regional Station, NBPGR Shillong in field operations and data collection.

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